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A note on publication and citation rates of female academics in earthquake engineering

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Abstract

Publication and citation rates of female engineering faculty (FEF) who work in earthquake engineering are analyzed and compared with a group of leading male engineering faculty (MEF) in the same field. After correcting for the effects of rank and gender, it is found that the future performance of FEF, given the opportunity, can rank as high as the recognized leaders in the field.

1. Introduction

The percentage of females among all professionals has increased from about 37% in 1984 to almost 50% in 2000, but at universities the percentage of female faculty continues to be small. Between 1984 and 1990, it increased only from 25% to 27%, although it experienced somewhat faster growth (from 27% to 37%) between 1990 and 1996. Since 1996, it has remained almost constant, between 36% and 37% (Fig. 1 (top); p. 28 of March 2002 issue of *Academe*).

A survey of engineering faculty at 236 American colleges and universities for the period 1996–2001 showed that at more than half (54%) of all institutions the number of female engineering faculty (FEF) has either decreased or remained the same. The number of female faculty at 18 institutions (8%) has doubled and the increase has been even larger at 22 other institutions (9%). The majority of the institutions reporting large percentage increases between 1996 and 2001 had only 1 or 2 female faculty members in 1996. Table 1 illustrates a sample of 23 universities with more than 10 FEF, and the respective increases in 2001. At eight of these institutions (highlighted by italics), the increase was equal to or greater than 50%.

In this study, we analyze the performance of a sample of female faculty in civil engineering, who specialize in earthquake engineering and related fields at US universities, and compare them with a cohort of senior and leading male faculty [1,2]. Because complete lists of publications are not generally available for faculty at all universities, we used the Earthquake Engineering Abstracts (EEA) database of the National Information Service for Earthquake Engineering (NISEE; http://nisee.berkeley.edu/eea.html) to approximate their *input* to the pool of scientific literature. The cited articles in the Thomson ISI database (http://www.isinet.com/ISI) were used to measure their successful *output*. The NISEE EEA database is at present the most complete source of information worldwide on published material in earthquake engineering and the related fields. It contains over 100,000 records (journal and conference papers, reports, and monographs) in structural mechanics, structural engineering, geotechnical engineering, and engineering seismology, since 1971. With few exceptions, it can be assumed that the number of abstracts in this database represents a lower bound of the number of contributions of the sample of faculty studied in this paper, in earthquake engineering. The EEA database could be accessed free of charge until January of 2004, when it became part of Cambridge Scientific Abstracts (CSA)—a privately owned information company located in Bethesda, Maryland, that publishes abstracts and indices for scientific and technical research literature (http://www.csa.com).

The HighlyCited.com of Thomson Institute for Scientific Information (http://www.isinet.com/ISI) publishes names of up to 250 of the world's most cited researchers in each of

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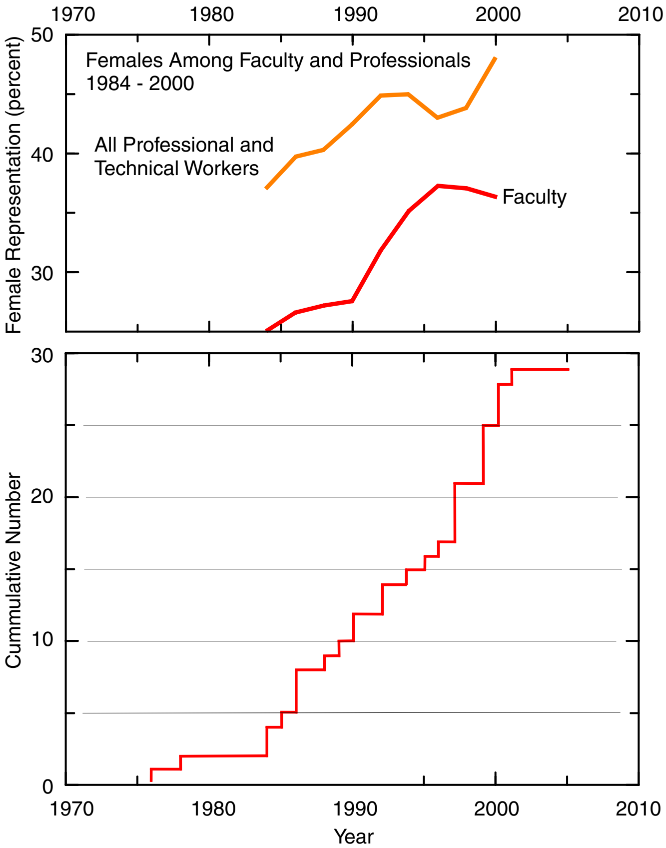

Fig. 1. Percentage of females among all professional and technical workers and among faculty, versus time, for the period between 1984 and 2000 (top), and arrival times (year of Ph.D.) of 29 female faculty and researchers in the field of earthquake engineering and related fields (bottom) (see also Table 3).

21 categories including life sciences, medicine, physical sciences, engineering and medical sciences. At present, there are no earthquake engineers in the category of engineering. In terms of an approximate metric used in this paper, citation threshold for engineering academics who work in related fields of mechanics and finite elements, and who are included in HiglyCited.com list, is about 6000 total uncorrected citations. The most cited earthquake engineers have about half that many citations. It appears that the absence of earthquake engineers from engineering category of HighlyCited.com is mainly the consequence of two facts, that: (1) nearly 80% of journal papers in civil engineering are not cited within 5 years after publication; and (2) that the cohort of earthquake engineers is very small relative to the membership of all other engineering disciplines combined [2].

Publication rates in earthquake engineering are close to the average rates for science and engineering professors in the US [1], and therefore may not be the reason for the absence of earthquake engineers in the HighlyCited.com list. One of the purposes of this paper is therefore to extend the work of Trifunac [2], by quantifying the publication and citation rates for a sample of female faculty in earthquake engineering. This should contribute to better understanding of their current contributions and may suggest how to extend and refine related future analyses.

2. A sample of FEF in earthquake engineering in the US

To identify FEF for our study, during 2002 and 2003 we surveyed the Web sites of civil engineering departments of

Table 1
Increase in the number of female engineering faculty, 1996–2001, at selected institutions reporting 10 or more female faculty in 1996

University	No. of female faculty		Change	% Change
	1996	2001		
Arizona State University	17	28	11	65
Boston University	10	13	3	30
Carnegie Mellon University	10	15	5	50
Colorado School of Mines	20	22	2	10
Cornell University	14	23	9	64
Georgia Institute of Technology	16	41	25	156
Iowa State University	18	20	2	11
Massachusetts Institute of Technology	25	38	13	52
Mississippi State University	14	17	3	21
North Carolina State University	12	16	4	33
Northwestern University	14	18	4	29
Ohio State University	21	29	8	38
Purdue University	20	31	11	55
Stanford University	13	15	2	15
Texas A&M University	21	25	4	19
University of Colorado, Boulder	15	24	9	60
University of Illinois, Urbana	24	35	11	46
University of Maryland, College Park	13	15	2	15
University of Massachusetts	11	13	2	18
University of Michigan	27	33	6	22
University of Minnesota	27	31	4	15
University of Texas, Austin	22	24	2	9
University of Wisconsin, Madison	11	19	8	73

about 40 universities in the US and recorded the names and basic biographical information on the female faculty on the tenure track with expertize in the areas of structural mechanics, earthquake engineering, and related fields. We did not include the faculty in environmental engineering, transportation, and construction.

In Table 2 we list 19 of the surveyed universities that, in December of 2003, did not have a female faculty member on the tenure track in the fields of interest for this study. Next, in Table 3, we list the FEF that we found. Columns (1) through (7) following the FEF number represent: (1) total number of abstracts in the NISEE database; (2) total number of ISI citations (as of January 10, 2004); (3) total number of cited articles (journal papers, reports, conference papers, etc.), in the ISI database; (4) year when Ph.D. was awarded; (5) number of years since Ph.D. degree; (6) average citation rate per cited article per year; and (7) current position. We have included in this sample one female faculty member who is on the research track and one senior female faculty member in architecture. The list in Table 3 contains the faculty who have a number of NISEE abstracts and ISI citations that are significant enough to present graphically in some of the further analysis. We found 17 other FEF, but we did not include them in Table 3 because as of December 2003 they had only a few or no citations in the NISEE and ISI databases. In several instances, duplicate family names and one or both initials, combined with similar or related professional activities of different authors in the ISI database made it difficult to separate the contributions of some faculty listed in Table 3. For example, Prof. D. Peric (FEF) specializes in constitutive modeling and failure analysis in soils, while Prof. D. Peric, who is a male faculty working in England, specializes in computational plasticity and friction modeling. This problem has been indicated by "?" in Table 3. Fig. 1 (bottom) shows the year of Ph.D. degree for 29 FEF, and thus it approximates the time of the beginning of their careers.

Table 2
A sample list of universities with no female faculty in civil engineering, except in the areas of environment engineering, transportation engineering, or construction management

Caltech	University of North Florida
Duke University	University of Oklahoma
Massachusetts Institute of Technology	University of South Florida (Tampa)
Oregon State University	University of Southern California
University of Central Florida	University of Virginia
University of Colorado at Boulder	University of Wisconsin-Milwaukee
University of Illinois-Chicago	University of California, Davis
University of Louisiana at Lafayette	University of California, Los Angeles
University of Michigan–Ann Arbor	University of California, San Diego
University of Nevada-Reno	

Even though our sample of FEF includes most female faculty in earthquake engineering in the US, the sample size is small and it is not homogeneous. Many factors contribute to the lack of homogeneity. For example, different universities provide different faculty resources. The high-ranking institutions tend to attract better students, and this can influence the productivity of their faculty. The teaching load can differ significantly among "teaching" and "research" universities, and so on. The publication productivity and citation rates also differ among different specialties (e.g. experimental versus theoretical work, design, dynamics of structures, soil mechanics, analysis of hazard, etc.), and therefore a small sample cannot describe these rates for different specialties within earthquake engineering. It will give only an approximation of these rates for the earthquake engineering as a whole, relative to other such groups in engineering. All of our results, explicit or implied, therefore must be viewed within those constraints.

In contrast the sample of male engineering faculty (MEF) which we will use here for limited comparisons with FEF, includes mainly senior professors in earthquake engineering, and is drawn from a large population of male faculty, at leading research universities, which provide good faculty resources. This MEF sample was not developed for comparison with FEF in this paper. It was selected and described by Trifunac [1,2] for different analyses, and will be used here only for general and qualitative comparisons, mainly because its characteristics are already known and readily available.

Fig. 2 shows a correlation plot of the cited articles in the ISI database and the number of NISEE abstracts, plotted on a logarithmic scale. It can be seen that FEF-14, FEF-13, FEF-6, FEF-7, and FEF-9 are above the 45° line. This implies that: (1) most of their articles are in the NISEE database; and (2) the percentage of their cited publications is high relative to those not cited. The other 12 points in Fig. 2 are 0.10–0.85 units below the 45° line, which corresponds to factors between 1.26 and 7.0 on the linear scale and implies that for these faculty one out of 1.26 to one out of 7 articles were cited. For FEF-5 and FEF-8 the number of NISEE abstracts appears to be incomplete and therefore those were not included in this figure. The NISEE database includes most of the important and recognized contributions, but not all journal papers, reports, conference papers, workshop proceedings, pamphlets, books, etc., while the Thomson ISI database includes citations made from articles published in about 6000 leading journals. Thus, a researcher who contributes many reports and conference articles will tend to have "larger" NISEE total count and "lower" Thomson ISI number of cited papers.

Fig. 3 compares (on a logarithmic scale) the total number of ISI citations as of January 2004 (see column 2 in Table 3) to the total number of articles in the NISEE database. As already shown in Table 3, FEF-1 has the largest number of NISEE abstracts (138), while FEF-9 has the largest number if ISI citations.

Table 3
Sample of female engineering faculty in civil engineering

Name	NISEE total (1)	ISI total citations (2)	ISI total articles (3)	Year of Ph.D. (4)	Years since Ph.D. (5)	(2)/(3)/(5) (6)	Current (January 2004) position (7)
FEF-1	138	194	60	1976	28	0.115	Professor
FEF-2	35	16	9	—	—	—	Professor
FEF-3	23	42	18	1984	20	0.117	Professor
FEF-4	22	68	8	1984	20	0.425	Professor
FEF-5	1	132	32	1985	19	0.217	Assoc. Prof.
FEF-6	25	74	27	1986	18	0.152	Professor
FEF-7	32	163	44	1986	18	0.206	Professor
FEF-8	3	24	12	1986	18	0.111	Professor
FEF-9	92	459	103	1988	16	0.278	Research Prof.
FEF-10	–	32	14	1989	15	0.152	Assoc. Prof.
FEF-11	2	167 (?)	8 (?)	1990	14	?	Assist Prof.
FEF-12	22	63	18	1990	14	0.25	Assoc. Prof.
FEF-13	19	70	31	1992	12	0.188	Professor
FEF-14	8	28	12	1992	12	0.194	Assist. Prof.
FEF-15	6	3	1	1994	10	0.3	Assoc. Prof.
FEF-16	2	25	6	1995	9	0.463	Assist. Prof.
FEF-17	2	15	7	1996	8	0.268	Assoc. Prof.
FEF-18	5	6	6	1997	7	0.143	Assist. Prof.
FEF-19	9	38	12	1997	7	0.452	Assist. Prof.
FEF-20	12	(?)	(?)	1997	7	—	Assist. Prof.
FEF-21	7	1	1	1997	7	0.143	Assist. Prof .
FEF-22	7	9	4	1998	6	0.375	Assoc. Prof.
FEF-23	13	6	3	1998	6	0.333	Assist. Prof.
FEF-24	13	12	5	1998	6	0.4	Assist. Prof.
FEF-25	0	16	5	1998	6	0.533	Assist. Prof.
FEF-26	0	5	3	1999	5	0.333	Assist. Prof.
FEF-27	12	6	5	1999	5	0.24	Assist. Prof.
FEF-28	0	18	7	1999	5	0.514	Assist. Prof.
FEF-29	3	0	0	2001	3	—	Assist. Prof.

(?) Duplicate names—cannot separate without detailed analysis.

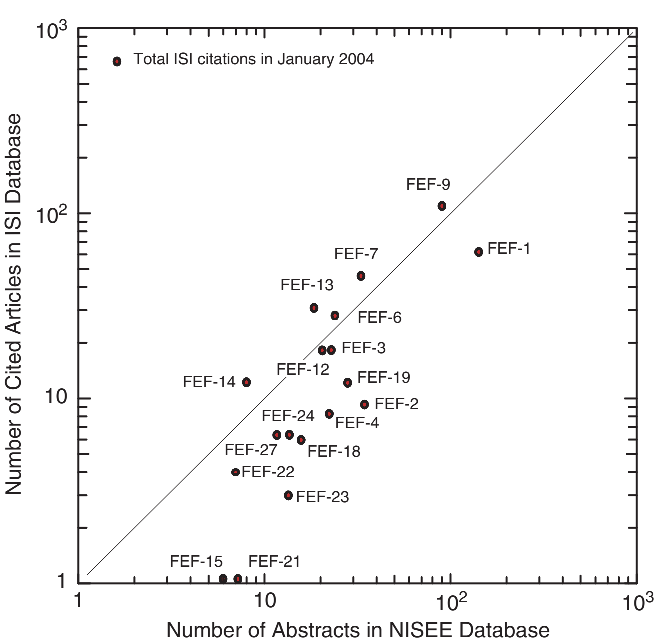

Fig. 2. Number of cited articles in the ISI database versus the number of articles in the NISEE database.

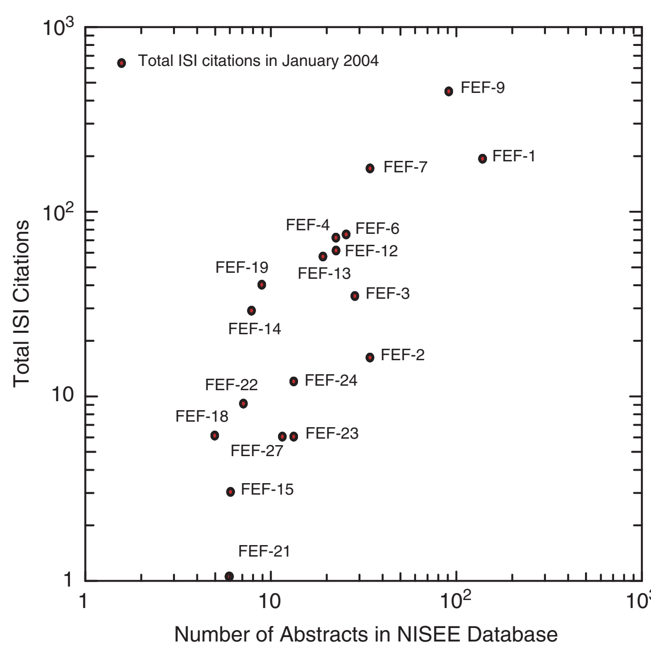

Fig. 3. The total number of ISI citations versus the number of abstracts in the NISEE database.

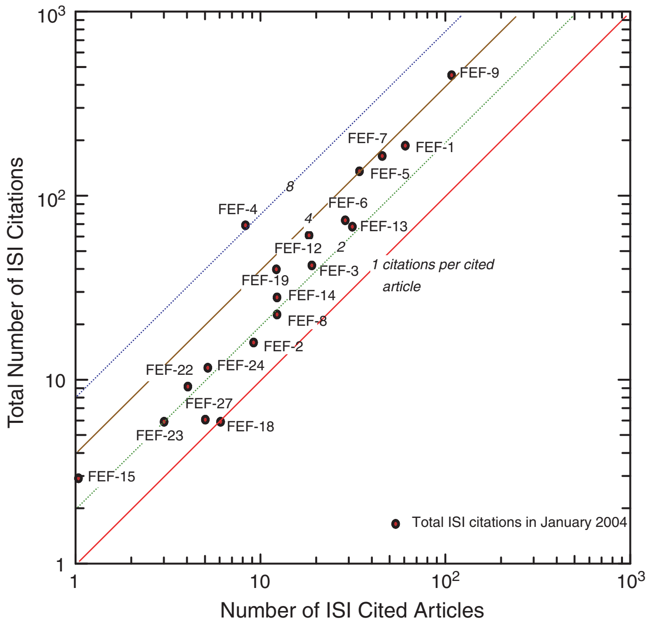

Fig. 4. Total number of citations in the ISI database versus the number of cited articles.

Fig. 4 compares the total number of ISI citations plotted versus the logarithm of the total number of cited articles in the ISI database. In the majority of cases for younger researchers, there are about two citations per cited paper. After 15–20 years of contributions to the field, the average approaches four citations per cited paper. Within this group, FEF-4 has the highest citation rate per cited paper. To eliminate the consequences of the length of observation (3–28 years, see Table 3), we can compute the citation rate per cited paper per year (equal to the total number of ISI citations divided by the product of the number of cited papers and the number of years since the awarding of the Ph.D.). The results are shown in Fig. 5. It can be seen in this sample that the citation rate (number of citations/number of cited papers/years since Ph.D.) is in the range from 0.111 (FEF-8) to 0.533 (FEF-25). These rates are also listed in column 6 of Table 3. We note that six of the female faculty included in Fig. 5 are not considered in Figs. 2–4 because as of January 2004 they did not have any NISEE abstracts (FEF-25, FEF-28, FEF-26, FEF-10) or only two abstracts (FEF-16, FEF-17).

3. A comparison with male researchers

An ideal comparison of our sample of FEF in earthquake engineering with a corresponding cohort of male faculty is difficult and beyond the scope of this paper. It would require selection of a set of male faculy with same or similar distributions in age, academic rank, specialty, at the same set of universities, and would have to use a complex selection process. For building the sample of FEF in this study we had little choice, but to include all candidates we could find during 2002 and 2003, because their population

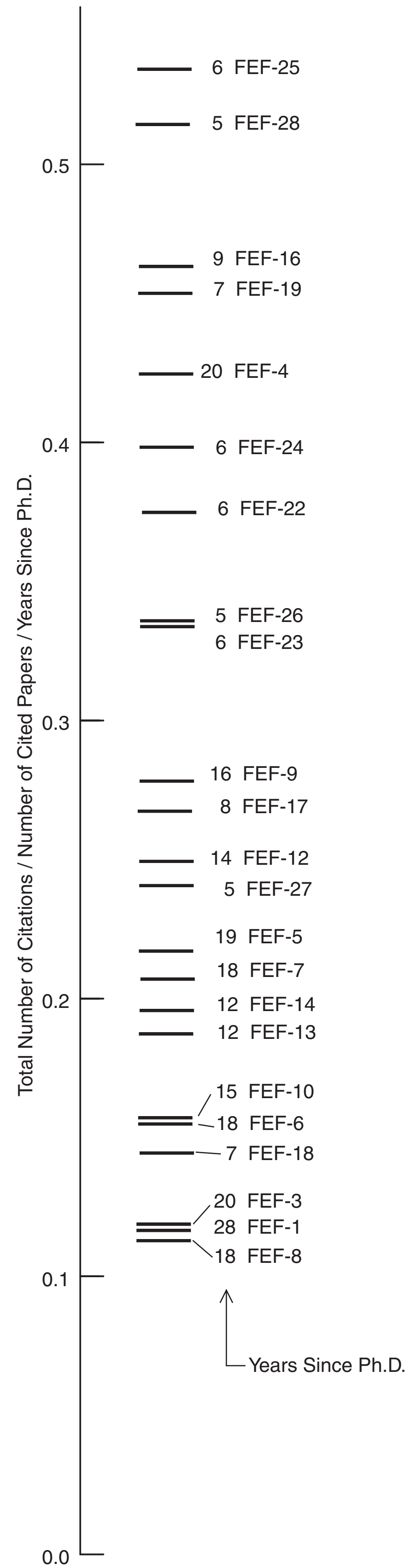

Fig. 5. Total number of citations per cited paper per year (measured since the year of Ph.D.).

has been and continues to be small. For male faculty the corresponding population is large and thus additional criteria would have to be adopted to select the sample. To avoid these difficulties we opted for a simple, albeit approximate, comparison. We used the previously studied sample of 49 male faculty in earthquake engineering, which is described in [1]. This sample is representative of senior male professors in earthquake engineering. To enable a limited comparison of MEF with FEF we will use statistical factors to "correct" for some of the known systematic differences, such as academic rank and gender, for example.

To maintain confidentiality, male faculty also have been assigned code names, which consist of an abbreviated code for the institution at which they work, followed by a number. The assignment of the names to this sequence has been random—that is, it is not based on the alphabetical order of names, seniority, or discipline. Table 4 (adopted from [1]) lists the abbreviations for 49 male faculty, and presents, for each institution, the number of the faculty members we included for this comparison. We made one exception to the above rule, in that we show the name of Maurice A. Biot (1905–1985). His unique position in the plots can serve as a benchmark of excellence [3].

Figs. 6a–c (modified from [1]) show the cumulative number of NISEE abstracts for 43 leading male faulty in earthquake engineering. The upper bound (about 10 papers per year) and lower bound (about one paper per year) determined by the curves in Fig. 6a are reproduced by wide lines in Figs. 6b and c in order to facilitate relative comparison of Figs. 6a–c. Fig. 7, plotted with the same scales as Figs. 6b–c, shows the corresponding results for nine female faculty. From Figs. 6a–c, and 7, it is seen that some of the female faculty are as productive as the most active male faculty.

Table 4
Institution codes and the number of male faculty considered in this study

Institutions	Code	No. of faculty considered in this study
American		
University of Southern California	USC	12
University of California, Berkeley	UCB	8
California Institute of Technology	CIT	3
University of California, San Diego	UCSD	3
Stanford University	SU	1
University of California, Irvine	UCI	2
University of Texas	UT	2
Columbia University	CU	2
State University of New York, Buffalo	SUNYB	2
Rice University	RU	2
University of Illinois, Urbana	UIU	2
University of Washington	UW	1
University of California, Los Angeles	UCLA	1
University of California, Davis	UCD	1
Johns Hopkins University	JH	1
Massachusetts Institute of Technology	MIT	1
Rensselaer P. Institute	RPI	1
European		
Imperial College, London, England	IC	1
Technical University of Athens, Greece	TUA	1
University of Ljubljana, Slovenia	ULJ	1
Royal Academy of Belgium	–	M.A. Biot

To compare the publication rates of the FEF studied in this paper to the national trends in the US, we use the mean publication rates of university professors for the period between 1960 and 2000, as reported by Bozeman and Lee [4]. They studied the careers of 443 science (59%) and engineering (41%) faculty with an average age of 46 in the year 2000, of whom 63% were tenured and 37% were not tenured, 87% were males and 13% were females, and 68% were native and 32% were immigrants. By using "normal count" [1,5,6], Bozeman and Lee presented the average number of publications per year versus time, starting with the year when the researchers received their doctoral degree. By integrating their results with respect to time, we can compute the cumulative average number of papers published by male researchers—US male average (USMA), and by female researchers—US female average (USFA). Those cumulative publication rates are shown by wide lines in Figs. 6a–c. It can be seen that FEF-1 and FEF-9 have publication rates that are well above USMA and USFA average trends. Fig. 7 further shows that the sample of FEF studied in this paper has similar overall average publication rates and similar spread about the mean trend as for the male faculty in earthquake engineering.

Fig. 8 shows the total number of ISI citations versus the total number of NISEE abstracts or equivalent (for M.A. Biot, and for USC-8, the NISEE database is incomplete, and so the total number of their published papers has been used instead), for male and female faculty. Fig. 9 shows the corresponding rates (the average number of ISI citations per year) versus the average number of NISEE abstracts per year. Because of the differences between FEF and MEF samples (age, rank, specialty, etc.), Figs. 8 and 9 cannot be interpreted to imply that FEF are less productive and less cited than MEF. We will address some of these differences in the next section.

Fig. 9 shows, for a subset of the female faculty listed in Table 3, the typical number of contributed abstracts (input = 0.7–6 per year) and the typical number of citations per year (output = 0.7–30 per year). It shows the same for 49 senior males faculty (input = 1–8 abstracts per year, and output = 8–100 citations per year).

4. Discussion

In this paper, we measure the productivity by the average publication rate (total number of publications divided by the number of years since the first publication) and refer to it as input productivity. Using the ISI database it is possible to refine the analysis and count only those inputs (papers) that have been cited, and to use those as a measure of recognized (output) productivity. The percentage of cited contributions varies widely among different faculty

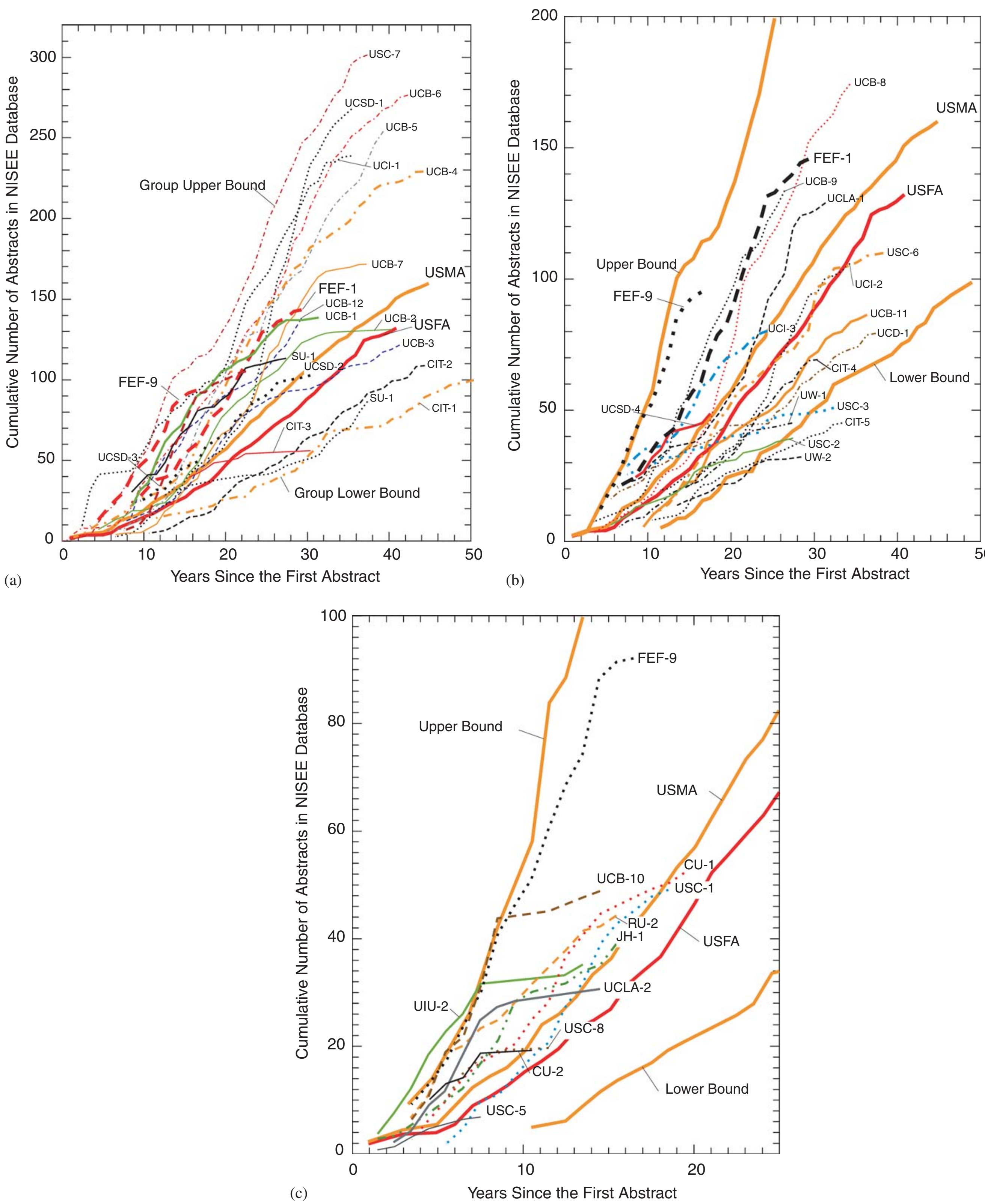

Fig. 6. (a) Comparison of the cumulative number of published articles in the NISEE database versus time (in years since the first citation) for 18 male faculty and two female faculty (FEF-1 and FEF-9) in earthquake engineering. (b) Same as (a), but for 15 different male faculty. For comparison, cumulative publications of two female faculty (FEF-1 and FEF-9) are shown also. (c) Same as (a), but for 11 ''younger'' academics (10 males and 1 female—FEF-9).

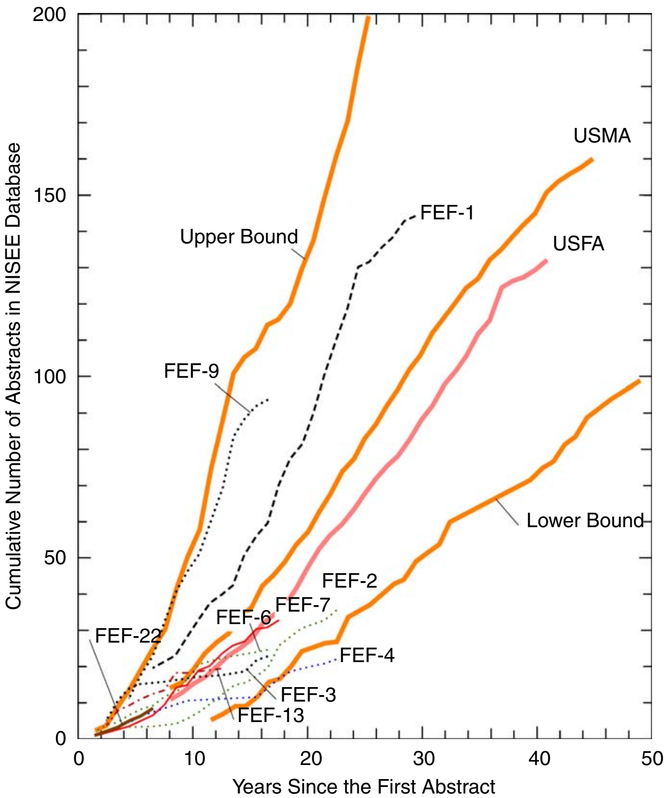

Fig. 7. Comparison of the cumulative number of abstracts in the NISEE database versus time (in years since the first citation) for nine female faculty in earthquake engineering (see also Table 3).

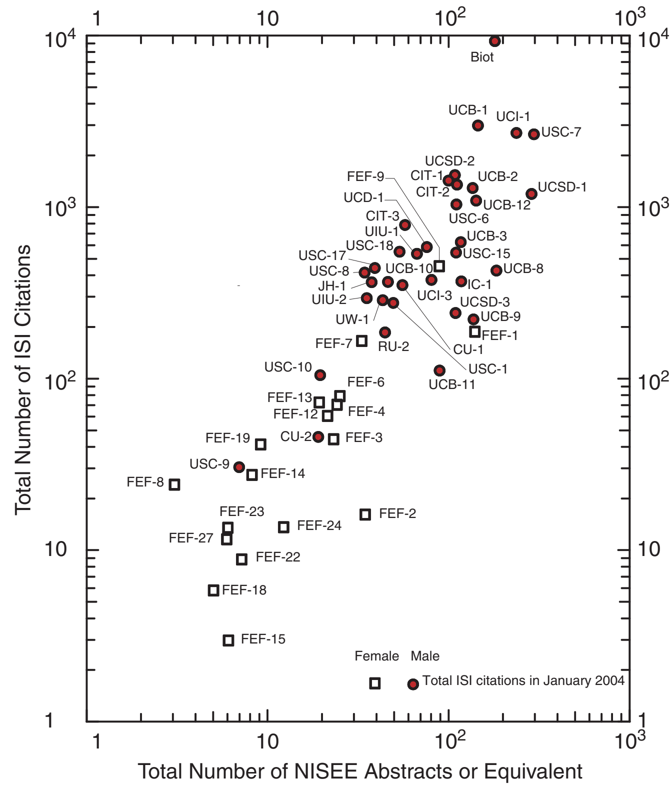

Fig. 8. Scatter plot of the total number of citations in the ISI database versus the total number of abstracts in the NISEE database, for samples of male and female academics in the fields of structural mechanics and earthquake engineering.

and different disciplines [7,8]. For a sample of 12 faculty in civil engineering (11 males and 1 female) studied by Trifunac and Lee [9], for example, the percentage of cited publications ranged from 12% to 95%.

Wanner et al. [10] argued that the research results in the sciences are reported in refereed journals and that other journal articles, books, and other publications are less used by researchers to advance the science. Thus, weighing the publications becomes an important bibliometric issue that is possible only within the study of particular disciplines.

Another important issue is how to distribute credit among the authors of a paper. Cole and Cole [11] proposed the use of "straight count," which allocates all credit only to the first author. This method assumes that the order of authors listed on the paper reflects the level of their contributions. The problem with this count is that it discriminates against those researchers whose name appears late in the alphabetic listing [12]. The second method is "adjusted count" (or "fractional count," or "per-author count"), which gives each author credit equal to $1/a_i$, where a_i is the number of authors. The advantage of the adjusted count is that it eliminates the bias in overestimating production when the value of co-authored paper is distributed among all contributors [13]. The third method is the "normal count," which gives full credit to all contributors regardless of the order of the listed authors. The problem with this count is that it is not reasonable to expect that all co-authors contributed equally, especially when some publications list authors for social reasons [5], or in the circles where the practice of making colleagues "honorary co-authors" is common [6]. In this work, we used the normal count.

4.1. Sample

Table 3 presents our starting sample of 29 FEF, 8 (28%) full professors, 6 (21%), associate professors, 14 (48%) assistant professors, and 1 (3%) research professor. According to the institution granting their doctoral degrees, this sample is distributed as follows: UC Berkeley—7 (25%); Stanford—5 (18%); University of Illinois—3 (11%); Cambridge University—2 (7%); and one each from—Cornell University; University of Southern California, University of Colorado in Boulder, Brown University, Princeton University, University of Texas at Austin; University of Michigan; Purdue University, Northwestern, UC Davis, and Tokyo University. Because of duplicate names, suspected incompleteness of the NISEE Abstracts, or lack of NISEE Abstracts or ISI citations, only a subset of 16–19 FEF from the above list of 29 could be used for further analysis and illustration of the trends.

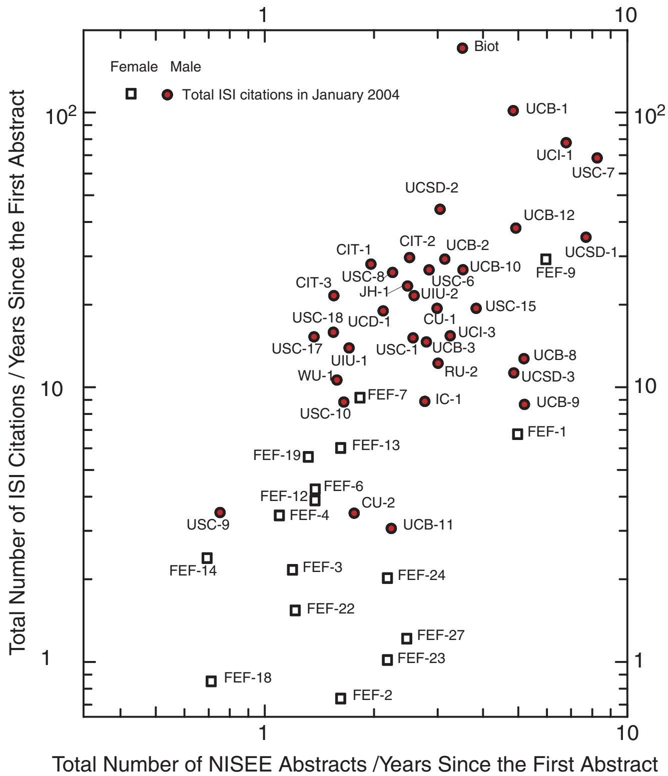

Fig. 9. Same as Fig. 8, but for the average citation rate per year versus the average number of abstracts in the NISEE database per year.

4.2. Age and rank

Major contributions for scientists and engineers occur in their 30s and 40s, 10–15 years into their careers [14], and then again between the age of 50 [15], and retirement [16]. Overall productivity increases with age, but with a gradually decelerating rate [17], and the tests of different reasons proposed for the decline of productivity with age show support only for two hypotheses: (1) a decrease in zeal and motivation with age and (2) a loss of breadth in knowledge through over-specialization [15]. Trifunac and Lee [9] studied variations in the number of journal publications per year for 10 faculty in earthquake engineering and found considerable variations in their productivity with time. Four faculty had a single peak in productivity in their late 30s or early 40s, two faculty displayed monotonically decreased productivity, and three had a peak in their late 30s and an increasing productivity after the age of about 50.

A study of the individual variations in the publication productivity with age of the sample of FEF studied in this paper could not be performed because of their young age. Almost half (48%) are assistant professors, and thus the lengths of the time windows available for analysis are too short to yield conclusive results.

Fig. 10 shows the mean number of publications of 443 scientists and engineers after they received their doctoral degree and gives insight into their productivity levels during the course of their careers [4]. The data show that

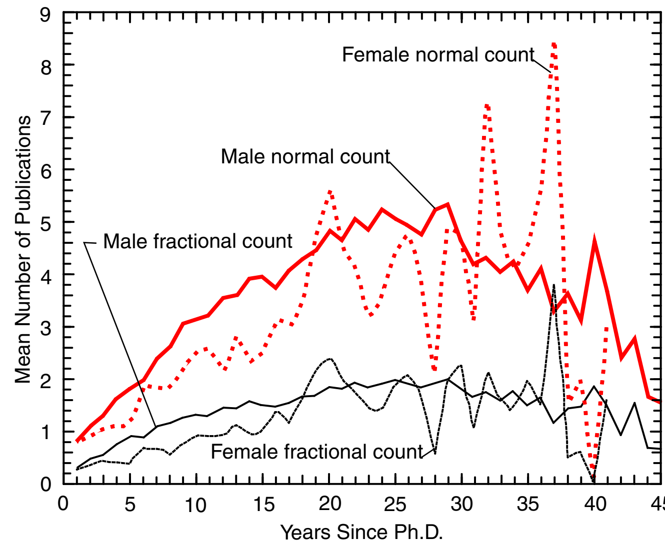

Fig. 10. Comparison of mean number of publications for male and female faculty plotted versus years after Ph.D. (from Bozeman and Lee [4]).

Table 5
Productivity of professors in engineering and sciences in terms of mean publications per year (normal count)[a]

Productivity by rank	Full professor 5.15	Associate professor 3.25	Assistant professor 2.82
Productivity by marital status	Married 3.91	Single 2.59	
Productivity by citizenship	Native 3.55	Non-native 4.34	
Productivity by gender	Male 3.96	Female 2.75	

[a]From Bozeman and Lee [4].

male productivity peaks between the 23rd and 28th year after Ph.D., averaging nearly five publications per year. After that, it drops to four publications for about 5 years and then to a little more than two, after 40 years. The average is less than three publications per year for the first 8 years—the time during which many young faculty are struggling to qualify for tenure. The productivity of female faculty is lower during the first 15–20 years of their careers, but then it equals and exceeds male productivity between 30 and 38 years after Ph.D. Time integrals of these mean publication rates give the cumulative number of publications for male (USMA) and female (USFA) faculty versus time (see Figs. 6a–c and 7).

Table 5 shows the productivity rates by rank. It is seen that the full professors produce significantly more than associate professors (58% more) and assistant professors (82% more).

4.3. Gender

Many studies have found somewhat lower production rates for women than for men [18–20] and have noted that obligations to family and children, as well as sex discrimination, may make it more difficult for females to compete for resources [21], which in turn may limit their ability to publish. In contrast to this stereotype that women are less productive, [10,22] found that the differences in the number of publications and citations increase during the first decade of the career but are reversed later in the career, so that the differences in life/time productivity are reduced (Fig. 10). At present, a decline in the effects of gender on scientific productivity may also be due to the increasing participation of females in scientific jobs [23].

In Fig. 11, we show the histograms of publication rates (NISEE abstracts/year) for the two samples (male and female) of earthquake engineering faculty. The histogram for male faculty is taken from the study by Trifunac [1] of 56 male professors in earthquake engineering. The histogram for female faculty is based on a subset of 18 FEF taken from Table 3 (FEF-1, 3, 4, 6, 7, 9, 12–15, 18–24, and 27). The remaining 11 FEF listed in Table 3 could not be included, primarily because of the small number of abstracts in the NISEE data/base, suggesting incomplete coverage, and in one case (FEF-2) because of the absence of a time scale (Table 3).

The histograms in Fig. 11 show that the average publication rate for the sample of male faculty is $\bar{x}_{\rm m} = 3.30$ publications/year, while for the sample of female faculty it is $\bar{x}_{\rm f} = 1.82$ publications per year. Of 18 FEF included in this histogram, 6 (33%) are professors, 4 (22%) are associate professors, and 8 (44%) are assistant professors. Using Bozeman and Lee's [4] analysis of the productivity rates by rank (Table 5), and using the weights of 0.333, 0.222 and 0.444 for the above six professors, four associate professors and eight assistant professors, respectively, the average "corrected" productivity rate for this sample of 18 FEF becomes about 3.69 papers per year. The histogram for male faculty in Fig. 11 is based on the publication rates of 54 professors, one associate professor and one assistant professor. The differences in average productivity by rank, shown in Table 5, then imply that the average publication rate for this male group should be about $5.15(54/56)+3.25(1/56)+2.82(1/56) = 5.07$ papers per year. Finally, the [4] data on the differences in average productivity by gender suggest a factor of $2.75/3.96 = 0.694$. Combining all of this and starting with average male publication productivity of $\bar{x}_{\rm f} = 3.30$ papers per year for MEF in earthquake engineering would predict the corresponding productivity of 18 FEF in the sample used in Fig. 11 to be $3.30 \times 0.694 \times 3.69/5.07 = 1.67$ papers per year. This is close (9% smaller) to the $\bar{x}_{\rm f} = 1.82$ computed directly from the histogram in Fig. 11. The sample of 18 FEF is not homogeneous and is obviously too small to consider the above calculation for average trends as significant. Nevertheless the result is of considerable interest, because it implies, as does Fig. 10, that with time the average publication rate of FEF in earthquake engineering may exceed the publication rate of male faculty.

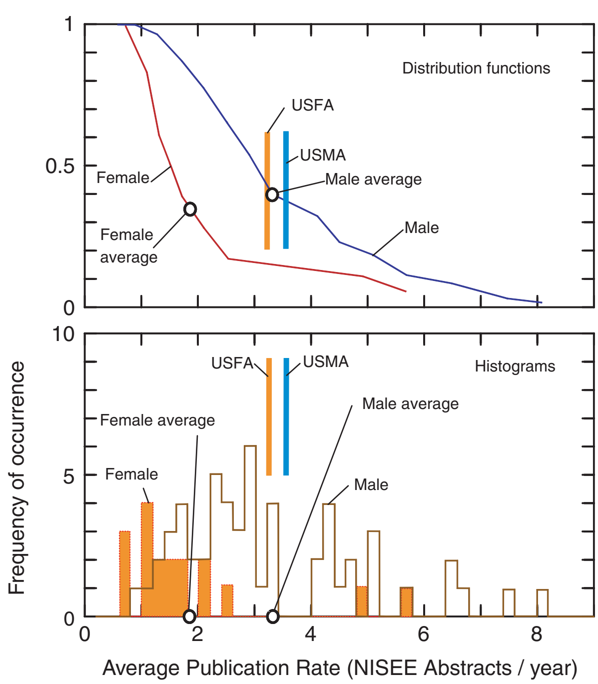

Fig. 11. Approximate distribution functions (top) and histograms showing frequency of occurrence of average publication rates (NISEE abstracts per year) (bottom) for two samples, one male and one female, of faculty in earthquake engineering. Averages of cumulative publication rates for male, US male average (USMA), and for female, US female average (USFA), faculty are shown for the general field of engineering and science.

Fig. 12 compares, for male and female samples, the average numbers of citations per NISEE abstract. For the 56 males, the average is $\bar{x}_{\rm m} = 7.18$ citations per NISEE abstract (without Biot), or $\bar{x}_{\rm m} = 7.97$ (with Biot). For the 12 FEF, the average is $\bar{x}_{\rm FEF} = 2.56$ citations per NISEE abstract.

Fig. 13 shows the average number of citations per NISEE abstract versus the number of abstracts per year for 43 male faculty (full circles, taken from [2]) and for 15 FEF (open circles) from Table 3 (FEF-1, 3, 4, 6, 7, 9, 12–14, 18, 19, 22–24, and 27). From among the 15 FEF, FEF-7, and FEF-9 have the highest citation rates, about six citations per abstract. The most prolific in the group are FEF-1 and FEF-9, with about five NISEE abstracts per year.

The differences in citation rates between male and female faculty, illustrated in Figs. 12 and 13, cannot be interpreted quantitatively. Citation rates depend upon the areas of specialization [24], the number of co-authors in the published papers, journal impact factors [25,26] of the journals where the work is published, the frequency of self-citations, rank, and many other factors [9,27]. In contrast to the publication rates, which have been studied extensively (e.g., see [1,4]), studies of the citation rates are now beginning to appear. Therefore it will take some time before it will be possible to compare our small male and female samples of faculty in earthquake engineering with other related samples in different engineering fields. In the meantime, the results of the present work may serve as

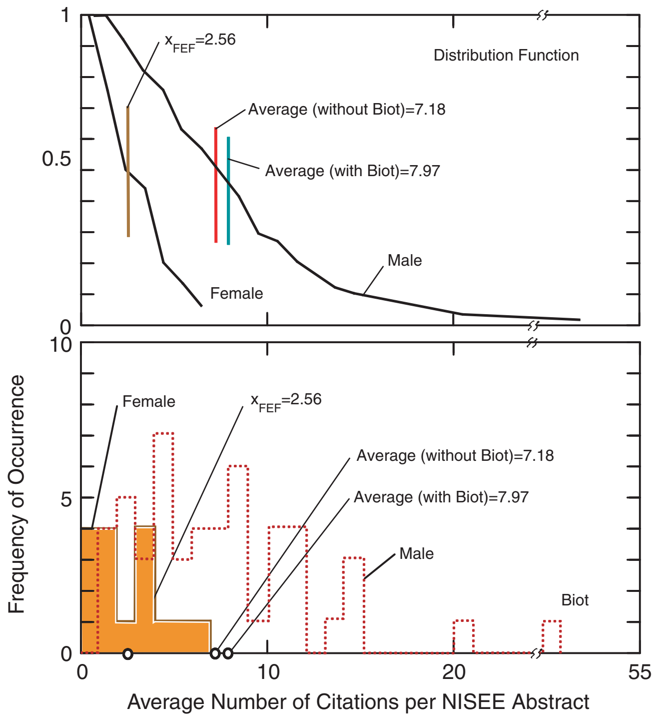

Fig. 12. Approximate distribution functions (top) and histograms showing the frequency of occurrence of the average number of citations per NISEE abstract (bottom) for the samples of male and female faculty in earthquake engineering. Note an interruption of the horizontal scale between ~24 and 50.

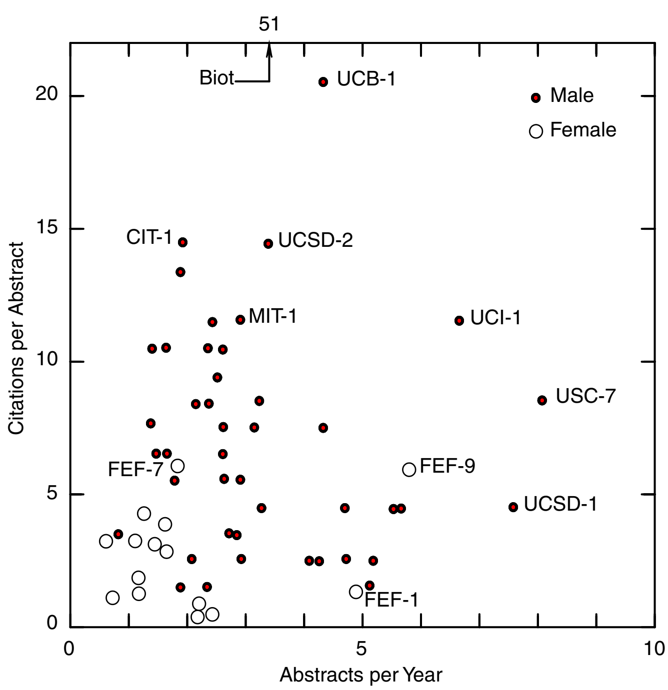

Fig. 13. Scattergram of citations per abstract (~paper) versus abstracts (~papers) per year for 49 males (solid points) and 15 females (○) faculty in earthquake engineering.

preliminary estimates contributing to a set of input (publication) rate and output (citation) rate scaling parameters that describe the bibliometric aspects of earthquake engineering.

4.4. Education

In a study of citation rates of male faculty in earthquake engineering, Trifunac [2] searched for correlations between citation and publication rates in terms of the institutions where those faculty obtained their doctoral degrees. Fig. 14 summarizes his results for 51 faculty (49 males and 2 females), who graduated from Caltech (CIT)–13 (25%); MIT–6 (12%); UC Berkeley—6 (12%); University of Illinois—5 (10%); University of Southern California—3 (6%); Columbia—2(4%); Stanford—2(4%); and SUNY at Buffalo—2 (4%). Of the 12 remaining ("Rest"), 5 (10%) have graduated, one each, from UC at Los Angeles, Illinois Institute of Tech; Rice University, University of Michigan, and Rensselaer Poly. Institute, and 7 (13%) have doctoral degrees from universities in Europe, Australia, Japan, New Zealand, and Israel. It was noted that the small size of the sample did not permit attaching statistical significance to the results, but that collectively the data suggest a decreasing trend of citation rates with increasing publication rates. The data suggest that the largest citation rates occur for publication rates less than about three NISEE abstracts (~papers) per year. The sample of female faculty studied in this paper is even smaller. Of 16 FEF for whom

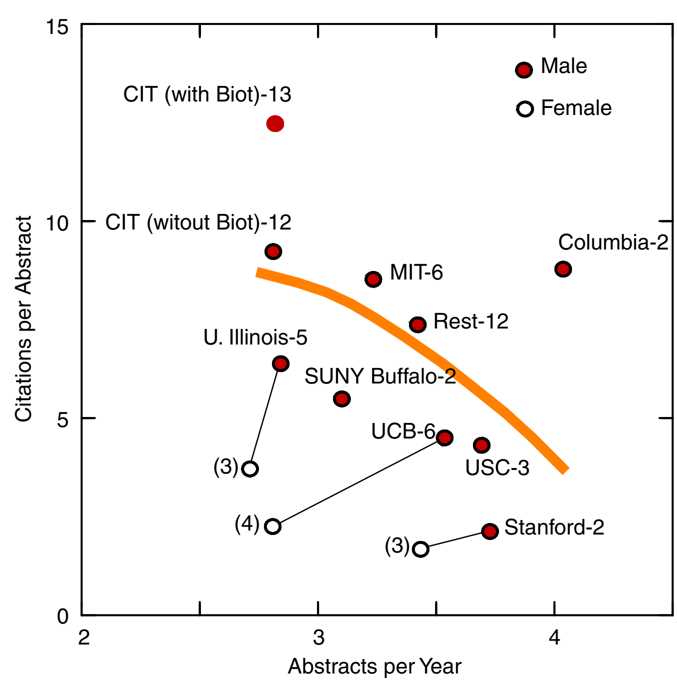

Fig. 14. Averages of citations per abstract (~paper) in NISEE database versus averages of abstracts (~papers) per year for institutions where 49 males (●) and 10 females (○) faculty obtained their doctoral degrees. The number of faculty used to compute the averages follows the short code or name of the university. For female faculty, this number is shown in brackets.

both citation and publication rates are available, four have doctoral degrees from UC Berkeley, three from Stanford, and three from University of Illinois at Urbana. Their group averages are included in Fig. 14 for completeness in this presentation only. The remaining five FEF have doctoral degrees from Brown University, Tokyo University, University of Southern California, University of Texas at Austin, University of Michigan, and Purdue University.

5. Conclusions

The results and trends described in this paper cannot be interpreted to mean that on the average FEF are not performing as well as their male counterparts, because of the differences in size of the pools of male and female faculty, the differences in distribution over ranks, and the way we sampled the female versus male faculty. The pool of male faculty is much larger than that of the female faculty, and even more so at the higher ranks. While our sample included most, if not all, female faculty in civil engineering who specialize in structural mechanics and earthquake engineering at leading research universities in the US, the sample of male faculty, taken from [1,2], is neither exhaustive nor random. Trifunac's sample of male faculty included mostly the older, and some retired (CIT-1, UCB-2, UCB-3) or deceased (Biot, UCB-1, UIU-1) leaders in their fields. In fact, the youngest male faculty members in his sample (JH-1, UCB-10, UIU-2, RU-2) are all at the full professor rank, except for one. In contrast, a large percentage of the female faculty in the sample studied in this paper are recent hires at the assistant professor rank. What is important to note about the rates in Fig. 9 is that 3 (FEF-1, FEF-9, and FEF-7) of the 17 female faculty considered in Figs. 8 and 9 (approximately 1 in 5) are equal to or outperform many of the MEF. If we considered all male academics in the related areas, it is almost certain that the corresponding fraction for them would be smaller than 1–5. Thus, given the opportunity FEF can rank as high as recognized leaders in the field of earthquake engineering, and we should look forward to their future significant contributions.

Trifunac [1] showed that the average publication rates of male faculty in earthquake engineering is essentially same as the average publication rates for engineering and science faculty in the US. He noted that the publication rates alone cannot be used to explain the absence of earthquake engineers from the HiglyCited.com. An important finding of this study is that the publication rates of female civil engineering faculty who specialize in earthquake engineering and related fields, are also close to the national average publication rates for female faculty in engineering and the sciences in the US. Therefore, up to January 2004, the publication productivity rate alone of both male and female faculty cannot be the reason for absence of earthquake engineers from the HighlyCited.com list of "most cited and influential researchers" in engineering.

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